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Feasibility Study Preliminary Documented Safety Analysis for In Situ Thermal Desorption in the Subsurface Disposal Area

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Idaho Completion Project

Bechtel BWXT Idaho, LLC

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Idaho Falls, Idaho 83415

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ABSTRACT

This Feasibility Study Preliminary Documented Safety Analysis is a safety basis analysis for in situ thermal desorption (ISTD) at the Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area at the Idaho National Engineering and Environmental Laboratory.

In situ thermal desorption is a soil remediation process in which heat and vacuum are applied to contaminated subsurface media. Pits being considered for treatment contain organic sludges, nitrate sludges, combustible solids, and graphite wastes, all of which are contaminated with plutonium. The objective of ISTD remediation is to remove or destroy these nonradioactive contaminants. Two major processes make up ISTD: (1) underground thermal desorption and destruction that occurs underground, and **(2)** treatment of off-gases produced during thermal desorption.

The hazard evaluation shows the highest hazards are from releases of radiological and nonradiological hazardous materials that would be generated through an accident in the ISTD treatment area, and failures in the ISTD well header piping and off-gas treatment system.

The analysis shows that ISTD can be conducted safely at the RWMC. To mitigate the accident consequences to facility workers, several systems or pieces of equipment must be designated safety-significant structures, systems, and components (SSCs). New technical safety requirements will be required to verify the operability and condition of the safety-significant SSCs.

EXECUTIVE SUMMARY

This executive summary provides an overview of the safety basis for in situ thermal desorption (ISTD) at the Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA) within the boundaries of the Idaho National Engineering and Environmental Laboratory (INEEL). Sufficient information is presented to establish a top-level understanding of ISTD at the SDA and the results of this Feasibility Study Preliminary Documented Safety Analysis (FS-PDSA).

The purpose of this FS-PDSA is to support remedial decisions for Operable Unit (OU) 7-13/14, which comprises the comprehensive remedial investigation and feasibility study for Waste Area Group (WAG) 7 at the INEEL. Waste Area Group 7 is the RWMC, which includes the SDA, a storage area for transuranic (TRU) waste, and miscellaneous support operations.

Information developed throughout the remedial investigation/feasibility study process is cumulatively evaluated to assess data collection activities, assumptions, and the overall strategy for completing the remediation of WAG 7. Administrative implementability is an uncertainty associated with candidate technologies for remediating the SDA. This FS-PDSA provides the basis for evaluating the safety issues and concerns associated with the technology and its implementation in the SDA.

E-1. FACILITY BACKGROUND AND MISSION

The RWMC was established in the early 1950s as a disposal site for solid low-level radioactive waste generated by operations at the INEEL and other U.S. Department of Energy (DOE) laboratories. Radioactive waste materials were buried in underground pits, trenches, soil vault rows, and one aboveground pad (Pad A) at the SDA. Radioactive waste from the INEEL was disposed of in the SDA starting in 1952. Rocky Flats Plant (RFP) TRU waste was disposed of in the SDA from 1954 to 1970. Post-1970 TRU waste was kept in interim storage in containers on asphalt pads at the Transuranic Storage Area (TSA) and is now being processed and shipped to the Waste Isolation Pilot Plant in New Mexico.

In August 1987, in accordance with the Resource Conservation and Recovery Act (RCRA)' Section 3008(h), DOE and the U.S. Environmental Protection Agency (EPA) entered into a Consent Order and Compliance Agreement.[2] The consent order and compliance agreement required DOE to conduct an initial assessment and screening of all solid and hazardous waste disposal units at the INEEL and set up a process for conducting any necessary corrective actions. On July 14, 1989, the EPA (under the authority granted to them by the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] of 1980,[3] as amended by the Superhnd Amendments and Reauthorization Act of 1986[4]) proposed that the INEEL be listed on the 1989 National Priorities List.[5] The final rule that listed the INEEL on the National Priorities List was published on November 21, 1989, in Title 54 of the Federal Register (FR) 48184, "National Priorities List of Uncontrolled Hazardous Waste Sites; Final Rule."[6] On December 4, 1991, because of the INEEL's listing on the National Priorities List, DOE, EPA, and the Idaho Department of Health and Welfare entered into the Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory.[7]

The strategy for assessing buried waste at the INEEL under the Comprehensive Environmental Response, Compensation, and Liability Act[3] includes the analyses of waste treatment technology options for the remediation of the RWMC. The waste under investigation is buried in the SDA within the RWMC. The types of remedial alternatives being evaluated for the buried waste include containment, in situ treatment, retrieval and ex situ treatment, and combinations of technologies. Seven preliminary remedial action alternatives for remediation of the SDA have been identified in the "Preliminary Evaluation of Remedial Alternatives for the SDA' (PERA) report.' The ISTD technology is one of the alternatives among the situ technologies under evaluation.

E-2. FACILITY OVERVIEW

In situ thermal desorption is a remediation process in which heat and vacuum are applied to subsurface contaminated media. Pits 4, 5, 6, and 10 are being considered for treatment. They contain organic sludges, nitrate sludges, combustible solids, and graphite wastes, all contaminated with plutonium. These wastes were disposed of in standard 55-gal drums. It is anticipated these drums have corroded and contaminated the 2 ft of soil underburden, all interstitial soil, and 1 ft of the soil overburden. The objective of ISTD remediation is to remove or destroy these nonradioactive contaminants.

Prior to treatment, soil will be placed on top of the current overburden soil to create 10 ft minimum total overburden. The purpose of 10 ft of overburden soil is to provide additional confinement in the event of an unanticipated reaction in the waste seam caused by the ISTD process. The 10 ft requirement is a preliminary estimate to be confirmed through ISTD field testing under design conditions.

Two major processes make up ISTD. First, the thermal desorption and destruction that occurs underground. Second, the treatment of off-gases produced during thermal desorption.

Thermal desorption occurs as heat flows into the contaminated media by conduction from heaters operated at 1,292–1,472°F. In situ thermal desorption temperatures remove and destroy the organic and nitrate contaminants of concern. In situ thermal desorption may also change the oxidation states, reducing their potential for transport.

Several ISTD modules may operate at one time, with each module treating 0.27 acres. Each of these modules will consist of six trailers: a control trailer, a standby power trailer, and four trailers for the off-gas treatment system. The major project facilities that make up a single ISTD module are:

- Heater wells
- Vacuum/heater wells
- Soil pressure monitors
- Thermocouple probes
- Header piping network
- Water drainage groundcover
- Off-gas treatment system
- Support facilities.

The vaporized constituents and degradation products will be drawn by vacuum into the off-gas treatment system. The off-gas system consists of high-temperature HEPA filters to remove particulate, thermal oxidation units to remove trace organics, dry scrubbers to remove acid gasses, and activated carbon adsorbers to remove any remaining contaminants.

The off-gas treatment system will require approximately 1,000 ft^2 of floor space and the equipment will be mounted on four semi trailers. Trailer-mounted components include a cyclone separator, high-efficiency particulate air (HEPA) filters, a regenerative oxidizer (which contains a propane burner and two ceramic oxidizing beds), a compact cross-flow heat exchanger, three dry gas scrubbers, three carbon adsorbers, two induced draft fans, and an exhaust stack.

The induced draft fans maintain a negative pressure in the well header piping network and pull the gas stream through the treatment processes on the trailers. Once the soil has been heated, it is essential that a vacuum be maintained throughout the rest of the remediation. In the event of a power outage, a standby generator will be used to maintain power to the off-gas system to ensure that gases are processed through the oxidizer and carbon beds. The heater and vacuudheater wells will be shut down upon loss of utility power to prevent the generation of additional gases.

E-3. FACILITY HAZARD CATEGORIZATION

The RWMC SDA had been designated as a Hazard Category 2 facility. Since this work is being performed in the SDA and involves intrusion into the waste, this activity is Hazard Category 2.

E-4. SAFETY ANALYSIS OVERVIEW

This section presents the methodology and results of the hazard analysis for ISTD. The hazard analysis is based on the entire SDA, which envelopes conditions found in the pits being considered for ISTD. The inventory in the SDA generally consists of solid radioactive waste from the INEEL, the RFP, and other off-site generators. This analysis addresses all waste types buried in the RWMC SDA, including transuranic (TRU) waste, contact-handled low-level waste (CH-LLW), and remote-handled low-level waste (RH-LLW). It also addresses nonradioactive contaminants that are part of the mixed TRU and LLW waste.

Transuranic waste is radioactive waste that contains alpha-emitting radionuclides with an atomic number greater than 92 (elements heavier than uranium) and a half-life greater than 20 years. When TRU waste was buried in the SDA, which was before 1970, it was defined to have an activity concentration greater than 10 nCi/g. TRU waste is of particular concern because of its long-lived radioactivity and high radiological dose consequences when inhaled. Transuranic waste disposal was terminated at the SDA in 1970. Subsurface Disposal Area Pits 1–6 and 9–12, and trenches 1–10 are known to contain TRU waste. Trenches 11–15 are also suspected to contain TRU waste. Rocky Flats Plant waste in drums and boxes was disposed of in Pits 11 and 12 through 1972. Later, these drums were retrieved and the TRU drums were placed in the Transuranic Storage Area. The boxes were left in Pits 11 and 12, so TRU waste could have been disposed of then. Also, there is a small number of TRU drums on Pad A.

Non-TRU waste is LLW that contains beta- and gamma-emitting radionuclides. Low-level waste is still being disposed of. Low-level wastes from the INEEL are in all pits and trenches, and include activation products and fission products from reactor operations, processing, and other activities. Low-level waste is classified by its handling requirements as contact-handled (CH) or remote-handled (RH). Remote-handled LLW has exposure rates above 500 mR/h at 1 m from the waste package surface. Subsurface Disposal Area shipping records show the SDA pits and trenches contain 861 packages with surface radiation exposure rates above 1 R/hr at the time of disposal. Dose rates for materials in the soil vaults have not been characterized, but are expected to be similar. Remote-handled LLW was buried in pits, trenches, and soil vaults.

The RWMC contains large quantities of nonradioactive contaminants. The most abundant and hazardous contaminants are sodium and potassium nitrates; organics, particularly carbon tetrachloride; and metals such as lead, beryllium, and zirconium.

Potential hazards associated with the project were identified through reviewing existing safety documents, design and process descriptions, operating history, and the DOE Occurrence Reporting and Processing System (ORPS) computer database.

In situ thermal desorption has been employed at eight nonradioactive sites. Most of these projects had no accidents or significant safety problems; however, a project at the Rocky Mountain Arsenal was terminated due to acidic corrosion of the aboveground off-gas piping.

A potential exists for energetic reactions to occur between the buried sodium and potassium nitrates and carbonaceous materials such as oil, charcoal, graphite, and cellulosic materials, when heated. A series of tests was conducted to evaluate the potential for these reactions to occur. Explosions and intense burning occurred. Explosive effects of the maximum credible combination can be mitigated by 10 ft of dirt overburden.

A what-if checklist-type analysis was also performed. The result is a comprehensive list of applicable hazards. All the hazards determined to be significant, or not routinely encountered, are further analyzed. The hazards evaluated are:

- Fissile material
- Ionizing radiation
- Radioactive material and nonradioactive hazardous material
- Fire/explosion
- Natural phenomena
- External events.

These hazards and associated accidents are identified and grouped (binned) in accordance with DOE-STD-3009-94.[9] The applicable hazards are evaluated qualitatively to identify potential unmitigated release or exposure scenarios. For each scenario, preventive and mitigative features are listed and consequence and frequency levels are assigned. The consequences and frequencies of accidents are combined in risk matrices to determine if safety-class or safety-significant structures, systems, and components **(SSCs)** are required, and if technical safety requirements (TSRs) or other safety requirements are needed.

The hazard evaluation shows the highest hazards are from releases of radioactive and nonradioactive hazardous materials that would be generated through an accident in the ISTD treatment area and failures in the ISTD well header piping and off-gas treatment system.

The ISTD system must be designed to incorporate operational safety features and protect workers from the hazards. These include the following safety significant features:

- Off-gas treatment system
- Induced draft fans
- Standby diesel generator

- Off-gas treatment stack monitoring system
- Soil pressure monitors.

In situ thermal desorption will be performed under the existing RWMC TSR requirements for operating and maintenance procedures. A TSR requiring a radiation protection program is not required because this program is required by 10 CFR 835.[10] The following new TSRs will be required to verify the condition of the ISTD safety significant systems.

- Verify operability and condition of off-gas treatment system, fans, and stack monitoring
- Verify operability and condition of standby diesel generator
- Establish and maintain soil cover depth
- Control heavy equipment access to ISTD-treated areas subject to subsidence
- Verify condition of fire protection program
- Design propane system to meet NFPA-58
- Verify operability of the soil pressure monitors.

A bounding and representative set of accidents was selected from the accidents identified in this hazard evaluation. The following design basis accidents were evaluated.

- Uncovering a high radiation source: Determines potential consequences from direct radiation exposure to a high-radiation package beneath the SDA surface.
- Underground drum explosion: Determines potential consequences from a fire or explosion in a single drum that expels material to the surface without taking credit for the mitigating affects of the additional soil cover.
- Well header piping failure: Bounds the consequences for a breach-type accident in the well header piping or off-gas system that causes immediate release of the contents.
- Off-gas system failure: Bounds the consequences of an accident where ISTD processing continues, but the waste gases are not treated by the off-gas system.
- Positive pressure in the subsurface treatment area: Bounds the consequences of an accident where hazardous materials escape from the ground before they are drawn into the off-gas well header piping. Potential causes are positive off-gas pressure from a fan failure, an underground fire, or other similar events.

The results from the quantitative analysis of exposures to radioactive and nonradioactive hazardous materials and a comparison of these results to evaluation guidelines established by the U.S. Department of Energy Idaho Operations Office (DOE-ID) are summarized in Table E-1 for radioactive materials and in Table E-2 for nonradioactive hazardous materials. Several accidents exceed the risk evaluation guidelines for the collocated worker, and for these safety-significant SSCs have been designated. No accidents exceed the risk evaluation guidelines for the public.

Table E-1. Postulated accident scenarios and results from analvsis of radioactive material releases.

Accident Scenario	Frequency Category	Collocated Worker Total Effective Dose Equivalent (TEDE) (Rem)	Worker Evaluation Guidelines for TEDE (Rem)	Public (6 km) TEDE (Rem)	Public Evaluation Guidelines for TEDE (Rem)
Uncovering a high radiation source					
- Limiting source term	Extremely unlikely	Low	100	Negligible	25
- Best estimate source term	Unlikely	Negligible	25	Negligible	5
Underground drum explosion					
- Limiting source term	Extremely unlikely	33	100	.046	25
- Best estimate source term	Unlikely	0.24	25	3.3E-4	5
Well header piping failure					
- Limiting source term	Extremely unlikely	0.01	100	1.5E-5	25
- Best estimate source term	Unlikelv	0.01	25	1.5E-5	5
Off-gas treatment system failure					
- Limiting source term	Extremely unlikely	9.7	100	0.08	25
- Best estimate source term	Unlikely	9.6	25	0.08	5
Positive pressure in the subsurface treatment area					
- Limiting source term	Unlikely	0	25	0	5
- Best estimate source term	Anticipated	0	5	0	0.5

Table E-2. Postulated accident scenarios and results from analvsis of nonradioactive material releases.

Accident/ Likelihood Category	Substance	Collocated Worker Exposure Concentration (mg/m^3)	Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
Direct radiation exposure					
Extremely unlikely	None	0	Not Applicable	0	Not Applicable
Unlikely	None	0	Not Applicable	0	Not Applicable
Underground drum explosion					
Extremely unlikely	Phosgene	35	4	0.048	0.8
	Hydrochloric acid	140	224	0.19	30
	Carbon tetrachloride Nitric acid	1500	4790	2.1	639
Unlikely	Phosgene	0.45	0.8	0.00061	0.4
	Hydrochloric acid	1.1	30	0.0016	4.5
	Carbon tetrachloride	26	639	0.036	128
Well header piping failure					
Extremely unlikely	Hydrochloric acid	28.7	224	0.039	30
	Phosgene	0.68	4	9.3 E-4	0.8
	Carbon tetrachloride	30.3	4790	0.041	639
Unlikely	Hydrochloric acid	0.73	30	0.001	4.5
	Phosgene	0.013	0.8	1.8 E-5	0.4
	Carbon tetrachloride	0.77	639	0.0011	128
Off-gas system failure					
Extremely unlikely	Hydrochloric acid	414	224	3.4	30
	Phosgene	9.8	4	0.081	0.8
	Carbon tetrachloride	436	4790	3.6	639
Unlikely	Hydrochloric acid	11	30	0.087	4.5
	Phosgene	0.19	0.8	0.0016	0.4
	Carbon tetrachloride	11.	639	0.091	128

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Table E-2. (continued).

Accident/ Likelihood Category	Substance	Collocated Worker Exposure Concentration (mg/m^3)	Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
Positive Pressure in the subsurface treatment area					
Unlikely	Hydrochloric acid	414	30	3.4	4.5
	Phosgene	9.8	0.8	0.081	0.4
	Hydrofluoric acid	10.2	16.4	0.084	1.5
Anticipated	Hydrochloric acid	10.6	4.5	0.087	0.75
	Phosgene	0.19	0.4	0.0016	0.4
	Carbon tetrachloride	11.1	128	0.091	60

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E-5. ORGANIZATIONS

Bechtel BWXT Idaho, LLC, is responsible for the environmental remediation program at the INEEL. The INEEL's Idaho Completion Project (ICP) executes this responsibility. The project manager reports directly to the Clean/Close RWMC project director.

Organizations conducting work in the RWMC are directly accountable to the Clean/Close RWMC facility authority/operations manager for work planning, control, execution, safety, and compliance.

E-6. SAFETY ANALYSIS CONCLUSIONS

This analysis shows that ISTD can be conducted safely at the RWMC. To mitigate the accident consequences to facility workers, several systems or pieces of equipment must be designated safety-significant SSCs. New TSRs will be required to verify the operability and condition of the safety-significant SSCs.

E-7. DOCUMENTED SAFETY ANALYSIS ORGANIZATION

Though this FS-PDSA follows the format and content delineated in DOE-STD-3009-94, "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports," references are made to the main body of the RWMC SAR and SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters,"" for site characteristic information and institutional program summary information required by DOE-STD-3009-94.

E-8. REFERENCES

1. 42 USC § 6901 et seq., "Resource Conservation and Recovery Act (Solid Waste Disposal Act)," *United States Code*, October 21, 1976.

2. Agreement DOE-ID, *Consent Order and Compliance Agreement,* U.S. Department of Energy Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; and the U.S. Geological Survey, July 10, 1987.

3. 42 USC § 9601 et seq., "Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA/Superfund)," *United States Code,* December 11, 1980.

4. PL 99-499, 1986, "Superhnd Amendments and Reauthorization Act of 1986 (SARA)," 100 Statutes 1728, *Public Law,* October 17, 1986.

5. 54 FR 29820, 1989, "National Priorities List for Uncontrolled Hazardous Waste Sites: Update #9, Federal Facilities Sites," FRL-3615-2, *Federal Register,* U.S. Environmental Protection Agency, July 14, 1989.

6. 54 FR 48184, 1989, "National Priorities List of Uncontrolled Hazardous Waste Sites; Final Rule," *Federal Register,* U.S. Environmental Protection Agency, November 21, 1989.

7. DOE-ID, *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory,* Administrative Record No. 1088-06-29-120, U.S. Department of Energy Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; and the Idaho Department of Health and Welfare, December 4, 1991.

8. Zitnik, James F., Aran T. Armstrong, Brian K. Corb, Mark H. Edens, Douglas B. Holsten, Patricia M. O'Flaherty, Janet Rodriguez, Tamara N. Thomas, Russell L. Treat, Wayne Schofield, Kira L. Sykes, 2002, *Preliminary Evaluation of Remedial Alternatives for the Subsurface Disposal Area*, INEEL/EXT-02-01258, prepared by CH2MHILL for the Idaho National Engineering and Environmental Laboratory.

9. DOE-STD-3009-94, 2000, "Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports," Change 1, U.S. Department of Energy, January 2000.

10. 10 CFR 835, 2002, "Occupational Radiation Protection," *Code of Federal Regulations*, Office of the Federal Register, February 2002.

CONTENTS

FIGURES

TABLES

ACRONYMS

ACGIH	American Conference of Government Industrial Hygienists
AE	Architectural Engineering
AMWTP	Advance Mixed Waste Treatment Project
ANSI	American National Standards Institute
ARARS	applicable or relevant and appropriate requirements
ARF	airborne release fraction
ASME	American Society of Mechanical Engineers
BLEVE	boiling liquid-expansion vapor explosion
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulation
CGA	Compressed Gas Association
CH-LLW	contact-handled low-level waste
COC	contaminant of concern
COCA	Consent Order and Compliance Agreement
CSE	criticality safety evaluation
DBA	design-basis accident
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
DR	damage ratio
EPA	U.S. Environmental Protection Agency
ERPG	Emergency Response Planning Guide
FDSA	final documented safety analysis
FFA/CO	Federal Facility Agreement and Consent Order
FR	Federal Register

FS-PDSA	Feasibility Study Preliminary Documented Safety Analysis
HEPA	high-efficiency particulate air
ICP	Idaho Completion Project
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
ISTD	in situ thermal desorption
IWTS	Integrated Waste Tracking System
LLW	low-level waste
LPF	leak path factor
MAR	material at risk
NEC	National Electric Code
NFPA	National Fire Protection Association
NPL	National Priorities List
NRH	nonradiological hazardous
ORPS	Occurrence Reporting and Processing System
OSH	occupational safety and health
PDSA	Preliminary Documented Safety Analysis
PLC	programmable logic controller
PPE	personal protective equipment
PRD	program requirements document
RCRA	Resource Conservation and Recovery Act
RF	respirable fraction
RFP	Rocky Flats Plant
RH-LLW	remote-handled low-level waste
ROD	Record of Decision
RWMC	Radioactive Waste Management Complex

SAR	Safety Analysis Report
SARA	Superhnd Amendments and Reauthorization Act of 1986
SDA	Subsurface Disposal Area
SSC	structure, system, and component
SST	series stainless steel
ST	source term
TEDE	Total Effective Dose Equivalent
TLV	threshold limit value
TLV-TWA	threshold limit value time-weighted average
TRU	transuranic
TSA	Transuranic Storage Area
TSDF	treatment, storage, or disposal facility
TSR	technical safety requirements
VOC	volatile organic compound
WAC	waste acceptance criteria
WAG	Waste Area Group
WC	water column
WGS	Waste Generator Services

Feasibility Study
Preliminary Documented Safety Analysis for In Situ Thermal Desorption in the Subsurface Disposal Area

1. SITE CHARACTERISTICS

1.1 Introduction

A description of the site characteristics important to understanding the safety basis of Idaho National Engineering and Environmental Laboratory (INEEL) and Radioactive Waste Management Complex (RWMC) facilities is contained in the INEEL Standardized Safety Analysis Report (SAR) Chapters, (SAR-100), Chapter 1, "Site Characteristics"' and in Chapter 1 of the RWMC SAR.[2] Specific site characteristics that directly affect the design or the hazard and accident analysis for in situ thermal desorption (ISTD) at the RWMC are identified in this chapter.

1.2 Requirements

The codes, standards, regulations, and U.S. Department of Energy (DOE) orders and standards pertaining to site characteristics are covered in Chapter 1 of SAR-100. There are no additional requirements that apply uniquely to ISTD.

1.3 Site Description

A site description of the INEEL and RWMC, including pertinent information on geography and demography is contained in Chapter 1 of SAR-100. A plot plan of the RWMC is shown in Figure 2-1. For calculating the potential consequences of postulated accidents to an off-site individual (the public), the distance from the RWMC to the nearest INEEL site boundary is 6,000 m to the south.

1.4 Environmental Description

Chapter 1 of SAR-100 contains descriptions of regional and local meteorology, hydrology, and geology. The SAR-100 descriptions of site meteorology, hydrology, and geology also provide the basis for extreme weather conditions found in the natural phenomena threats design of ISTD. There are no additional environmental features or requirements unique to ISTD.

1.5 Natural Phenomena Threats

Specific natural phenomena threats (hazards) that are potential accident initiators for INEEL facilities are identified in Chapter 1 of SAR-100. See Chapter *3* for details.

1.6 External Manmade Threats

External manmade threats, exclusive of sabotage and terrorism,[a] that could be accident initiators for ISTD operations are identified and evaluated in Chapter 3 of this Feasibility Study-Preliminary Documented Safety Analysis (FS-PDSA).

1.7 Nearby Facilities

Postulated events identified and evaluated in Chapter 3 involving ISTD operations could negatively impact nearby RWMC facilities. A radioactive or nonradioactive hazardous material release could require the evacuation of nearby RWMC facilities.

Chapter 1 of SAR-100 describes hazardous operations at nearby INEEL facilities that could adversely impact RWMC facilities. INEEL facilities located within 15.3 km (9.5 mi) of RWMC are the Central Facilities Area (CFA) and the Idaho Nuclear Technology and Engineering Center (INTEC). No accidents at these facilities have been identified that could adversely impact ISTD operations beyond a possible need for RWMC evacuation.

The Advance Mixed Waste Treatment Project (AMWTP) is located within the boundary of the Transuranic Storage Area (TSA) at the RWMC. Another contractor operates the AMWTP for DOE. Accidents that would adversely impact ISTD operations beyond a possible need for evacuation of RWMC are not anticipated.

1.8 Validity of Existing Environmental Analyses

Chapter 1 of SAR-100 addresses the validity of existing environmental analyses. The site characteristic assumptions contained in this SAR are compatible with those of existing environmental analyses and impact statements (e.g., the Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement[3]).

1.9 References

1. Idaho National Engineering and Environmental Laboratory, *INEEL Standardized Safety Analysis Report (SAR) Chapters,* Chapter 1, "Site Characteristics," SAR-100, Rev. 0 (hereinafter cited as SAR-100).

2. *Radioactive Waste Management Complex Safety Analysis Report,* INEEL-94/0226, Revision 5, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho, October 20, 2000.

3. DOE/EIS-0203-F, "Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement," U.S. Department of Energy, April 1995.

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a. The analysis of postulated accidents caused by sabotage and terrorism is not within the scope of the ISTD PDSA. Identifying and controlling the risk of potential sabotage and terrorist threats at the RWMC is the responsibility of INEEL and RWMC security.

2. FACILITY DESCRIPTION

2.1 Introduction

In situ thermal desorption (ISTD) is a soil remediation process in which heat and vacuum are applied to subsurface contaminated media. Heat flows into the contaminated media by conduction from heaters operated at 1,292–1,472°F. In situ thermal desorption temperatures remove and destroy organic and nitrate contaminants of concern (COCs) in the Subsurface Disposal Area (SDA). In situ thermal desorption may also change the oxidation states of active COCs—reducing their potential for transport. The vaporized constituents are drawn by vacuum into an off-gas treatment system that removes any remaining contaminants.

In situ thermal desorption is a highly effective means of removing volatile organic compounds (VOCs) and nitrate wastes.

The information presented in this chapter is of sufficient depth and breadth to allow an independent reader to develop an understanding of the structure and operations of ISTD as it applies to the waste to be treated at the SDA and to perform the hazard analysis in Chapter 3. Information presented in this section includes the following:

- A brief overview of the SDA
- A description of proposed ISTD facilities
- A description of major equipment
- A description of the process and support equipment
- The identification and description of the confinement systems
- The identification and description of the safety-support systems
- The identification and description of the utility and support systems.

2.2 Requirements

The requirements that apply to this facility are found in the following documents:

- 10 Code of Federal Regulation (CFR) 830 Subpart B, “Safety Basis Requirements”
- 10 CFR 835 Subpart K, “Design and Control”
- DOE Order 420.1A, “Facility Safety”
- DOE Order 5480.23, “Nuclear Safety Analysis Reports”
- DOE-ID Architectural Engineering Standards.

2.3 Facility Overview

The Radioactive Waste Management Complex (RWMC) was established in the early 1950s as a disposal site for solid low-level waste generated by operations at the INEEL and other DOE laboratories. Radioactive waste materials were buried in underground pits, trenches, soil vault rows, and one aboveground pad (Pad A) at the Subsurface Disposal Area (SDA). Two types of solid radioactive waste are located in the SDA, transuranic (TRU) waste and low-level waste (LLW). Transuranic waste is radioactive waste that contains alpha-emitting radionuclides with an atomic number greater than 92 (elements heavier than uranium) and a half-life of greater than 20 years. During the period when TRU waste was buried in the SDA, TRU was defined to have an activity concentration greater than 10 nCi/g. Low-level waste is non-TRU waste that contains beta- and gamma-emitting radionuclides. Low-level waste is still being disposed of at the SDA. Transuranic waste from the Rocky Flats Plant (RFP) was disposed of in the SDA from 1954 to 1970. After 1970, incoming shipments of TRU waste were placed in interim storage in containers on asphalt pads at the Transuranic Storage Area (TSA). The RFP, a DOE-owned facility located west of Denver, Colorado, primarily produced components for nuclear weapons.

In August 1987, pursuant to the Resource Conservation and Recovery Act (RCRA) Section 3008(h), DOE and the Environmental Protection Agency (EPA) entered into a Consent Order and Compliance Agreement (COCA). The COCA required DOE to conduct an initial assessment and screening of all solid waste and/or hazardous waste disposal units at the INEEL and to set up a process for conducting any necessary corrective actions. On July 14, 1989, the EPA (under the authority granted to them by the *Comprehensive Environmental Response, Compensation and Liability Act of 1980* [CERCLA] [42 USC § 9601 et seq.], as amended by the *Superfund Amendments and Reauthorization Act of 1986* [SARA]) proposed that INEEL be listed on the National Priorities List (NPL) (54 Federal Register [FR], FR 29820). The final rule that listed the INEEL on the NPL was published on November 21, 1989, in 54 FR 44184. On December 9, 1991, because of the INEEL's listing on the NPL, DOE, EPA, and the Idaho Department of Health and Welfare entered into the Federal Facility Agreement and Consent Order (FFA/CO). Under the FFA/CO, the INEEL is divided into 10 waste area groups (WAGs). These WAGs are further subdivided into operable units (OUs). The RWMC has been designated as WAG 7 and is subdivided into 14 OUs.

The strategy for evaluating buried waste at the INEEL under CERCLA includes the analyses of waste treatment technology options for the remediation of the RWMC. The waste under investigation is buried in the SDA within the RWMC. The types of remedial alternatives being evaluated for the buried waste include containment, in situ treatment, retrieval and ex situ treatment, and combinations of technologies. The ISTD technology is one of the alternative in situ technologies under evaluation and is a possible alternative for remediation of OU 7-13/14, which comprises the comprehensive remedial investigation and feasibility study for the RWMC.

The SDA, shown in Figure 2-1, encompasses 96.8 acres of land on the western portion of the RWMC. The area includes Pad A, trenches, pits, and vaults that have been used for disposal. Currently, only pits 17 through 20 and concrete-lined vaults are used to dispose of LLW. Dikes and drainage channels are appropriately located to channel water away from the SDA to prevent flooding. In situ thermal desorption is only being considered for TRU pits and trenches, and probably only a subset of these. Waste on Pad A may be transferred to a pit for disposal. Pit 9 remediation activities are conducted at the SDA, but are not within the scope of this document.

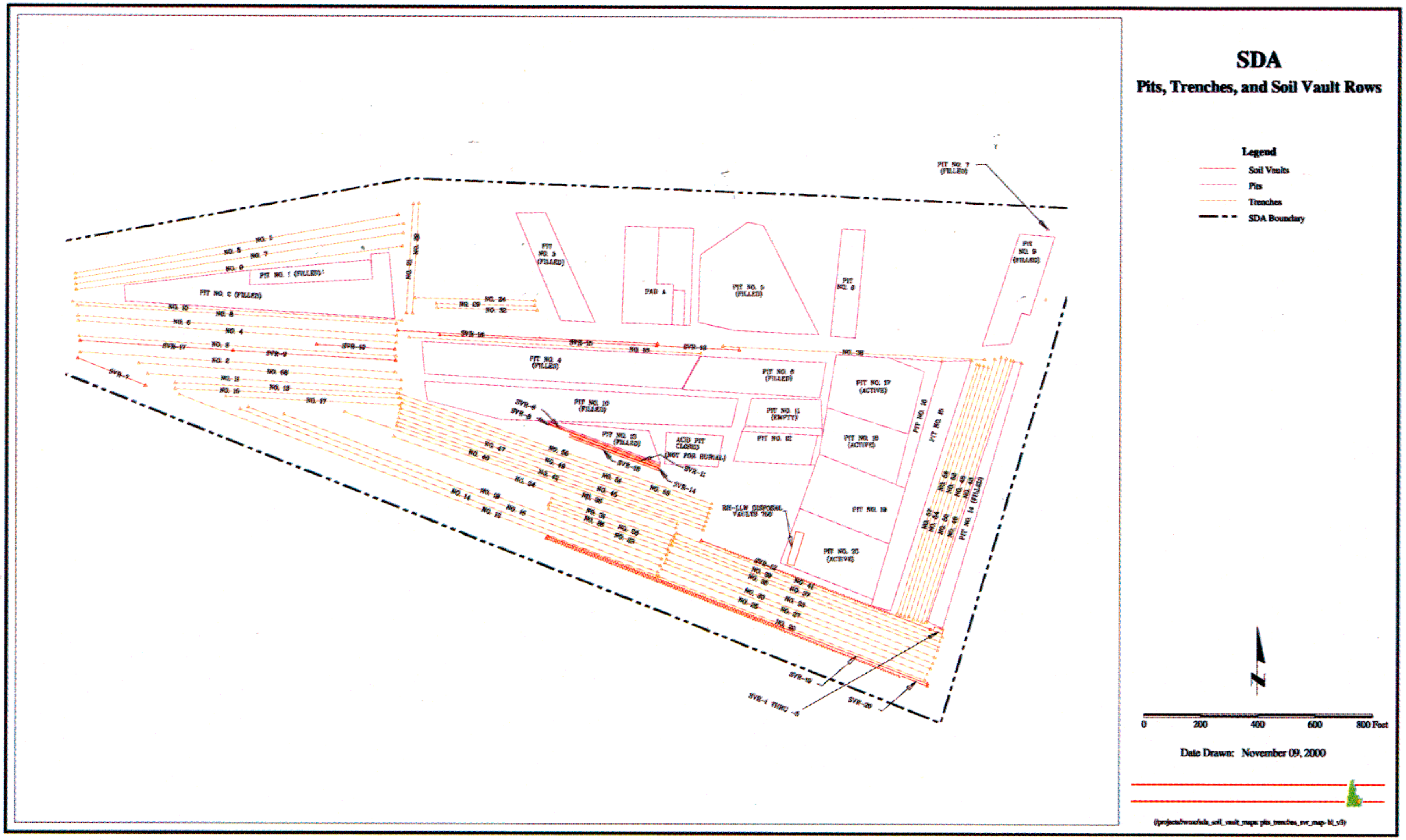

Figure 2-1. Subsurface Disposal Area.

2.3.1 TRU Pits and Trenches

There are 20 disposal pits and 58 trenches within the SDA. They are defined as TRU Waste pits and trenches or LLW pits and trenches, depending on their contents. In situ thermal desorption will only be used for TRU pits and trenches. Waste has been disposed of in drums, cardboard, wooden, and metal boxes, and other containers. Most containers are breached. The types of waste and the radioactive and nonradioactive hazardous source terms are described in Chapter 3.

The TRU pits and trenches are those that operated between 1952 and 1970, when both LLW and TRU waste were mingled for burial at the SDA. Waste from onsite generators was primarily LLW. From 1960 until 1963, LLW was also accepted from AEC licensed private entities. TRU waste was received from Rocky Flats Plant (RFP) and other generators beginning in 1954. Burial of TRU waste was discontinued in 1970. Much of this waste also contained nonradioactive hazardous material. Pits 1–6 and 9–12 and trenches 1–10 are known to contain TRU waste. Trenches 11–15 are suspected to contain TRU waste. The remaining pits and trenches contain only LLW.

Trenches were used for all ranges of radioactive waste, including both contact-handled (CH) and remote-handled (RH). From 1952 through 1957, the waste was buried only in trenches. Trenches were excavated to basalt and averaged 6 ft wide, 900 ft long, and 13 ft deep. Some trenches were excavated to the underlying basalt. In the late 1960s, the minimum trench depth increased from 3 ft to 5 ft, the bottoms of excavations were lined with at least 2 ft of soil under burden, waste was compacted by dropping a heavy steel plate on the waste in some trenches, and the soil cover was increased from a minimum of 2 ft to 3 ft. Adjacent trench centerlines were separated by no more than 16 ft.

Waste with high radiation levels was handled remotely using special shielded containers and boom cranes. As waste disposal became more rigorously controlled, the trenches were used more regularly for high radiation waste until soil vaults replaced them. For some trenches, metal liners were placed over the trench as it was filled. The metal liners prevented the trench from sloughing off and provided shielding. Concrete monuments identify locations of trenches. A brass plate on each monument is stamped with the trench number and the opening and closing dates.

Beginning in 1957, the larger open pits were excavated for disposal of large bulky items. Initially, waste was stacked horizontally in pits. From 1963 until 1969, drums from RFP were dumped into pits rather than stacked, to reduce labor costs and personnel exposure. The pits are approximately 100 ft wide, 13–32 ft deep, and vary in length from 200 to 1,200 ft. Concrete monuments mark corners of pits. A brass plate on each monument includes the pit number, boundary directions, and the opening and closing dates.

2.3.2 Waste Treated by ISTD

In situ thermal desorption is being considered for treating areas of the SDA containing organic sludges, nitrate sludges, combustible solids, and graphite from the RFP. These wastes were disposed of in the SDA pits and trenches in standard 55-gal drums. It is anticipated these drums have corroded and contaminated the 2 ft of soil underburden, all interstitial soil, and 1 ft of the soil overburden. The objective of ISTD remediation is to remove/destroy these contaminants of concern.

2.3.3 Estimated Treatment Area for ISTD in the SDA

Figure 2-2 is a map generated using the WasteOScope[1] system depicting SDA disposal locations with any evidence of organic sludge or nitrate sludge drum disposals. Inferred drum disposal densities are indicated in increments of 0–1, 1–3, 3–5, 5–10, and 10–15 drums per square meter of disposal area. Contiguous disposal areas were grouped and a 5-ft-wide 'buffer' area circumscribed to allow for uncertainty of disposal location. The total identified area was 112,754 square feet, or 2.6 acres. This is approximately 15% of the total disposal area for TRU pits and trenches, excluding Pad A. Only 3 of 19 contiguous treatment areas were greater than one-quarter acre in size (1.03, 0.44, and 0.30 acre).

2.4 Facility Structure

This FS-PDSA uses design and process information available March 2003. Additional information on facility design will be provided in the preliminary documented safety analysis (PDSA). The major project facilities that make up a single ISTD module are as follows:

- Heater wells
- Vacuum/Heater wells
- Soil pressure monitors
- Thermocouple probes
- Header piping network
- Water drainage ground cover
- Off-gas treatment system
- Support facilities.

Four ISTD modules will operate at one time, with each module treating 0.27 acres. Each of these modules will consist of six trailers—a control trailer, a standby power trailer, and four trailers for the off-gas treatment system.

Prior to treatment, overburden soil will be placed on top of the current overburden, to create 10 ft minimum total overburden. Heater wells, vacuudheater wells, and other subsurface devices will be driven through this overburden, through the waste matrix, through the underburden layer, to the basalt below. The vacuumheater wells will be slotted in order to remove the vapors created during the ISTD process. The vapors removed through the vacuum will be carried to the off-gas treatment system. Heat will be generated in the heater wells by resistant-electric heaters.

The 10 ft of overburden is a process assumption. The purpose of 10 ft of overburden soil is to provide additional confinement in the event of an unanticipated reaction in the waste seam caused by the ISTD process. The 10 ft requirement is a preliminary requirement that needs to be confirmed through ISTD field-testing. This preliminary requirement was derived from in situ vitrification-like testing (not ISTD) of worst-case mixtures.[2]

The heater wells will be arranged in a hexagonal pattern around vacuudheater wells. The heater wells will be 7 ft apart with vacuudheater wells in the middle of the hexagonal pattern, as shown in Figure 2-3. The vacuudheater wells will be 12.12 ft apart. The 0.27-acre area to be treated is approximately 122 x 97 ft, equating to 96 vacuumheater wells and 216 heater wells per module.

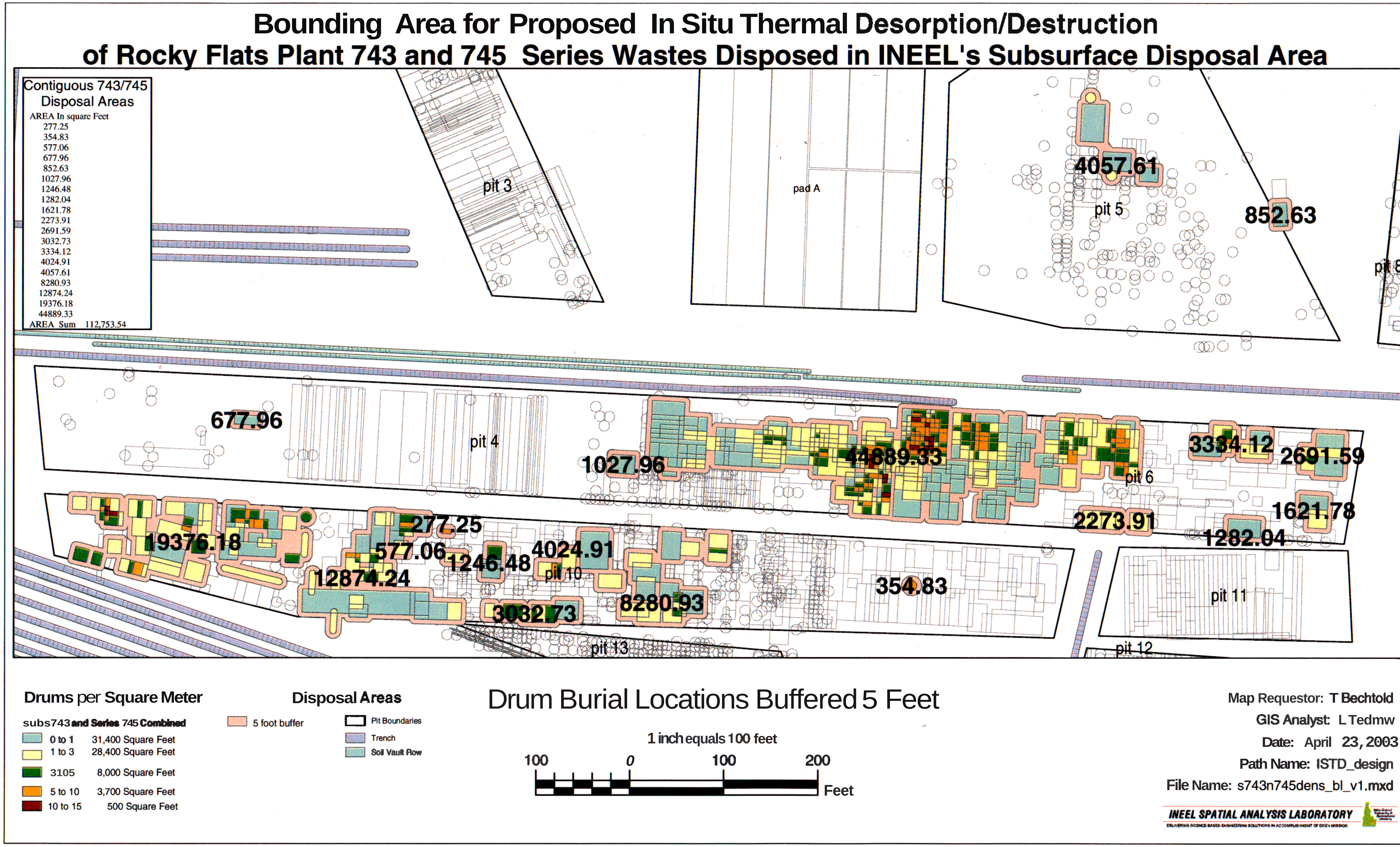

Figure 2-2. SDA disposal locations of drums containing any organic or nitrate sludge.

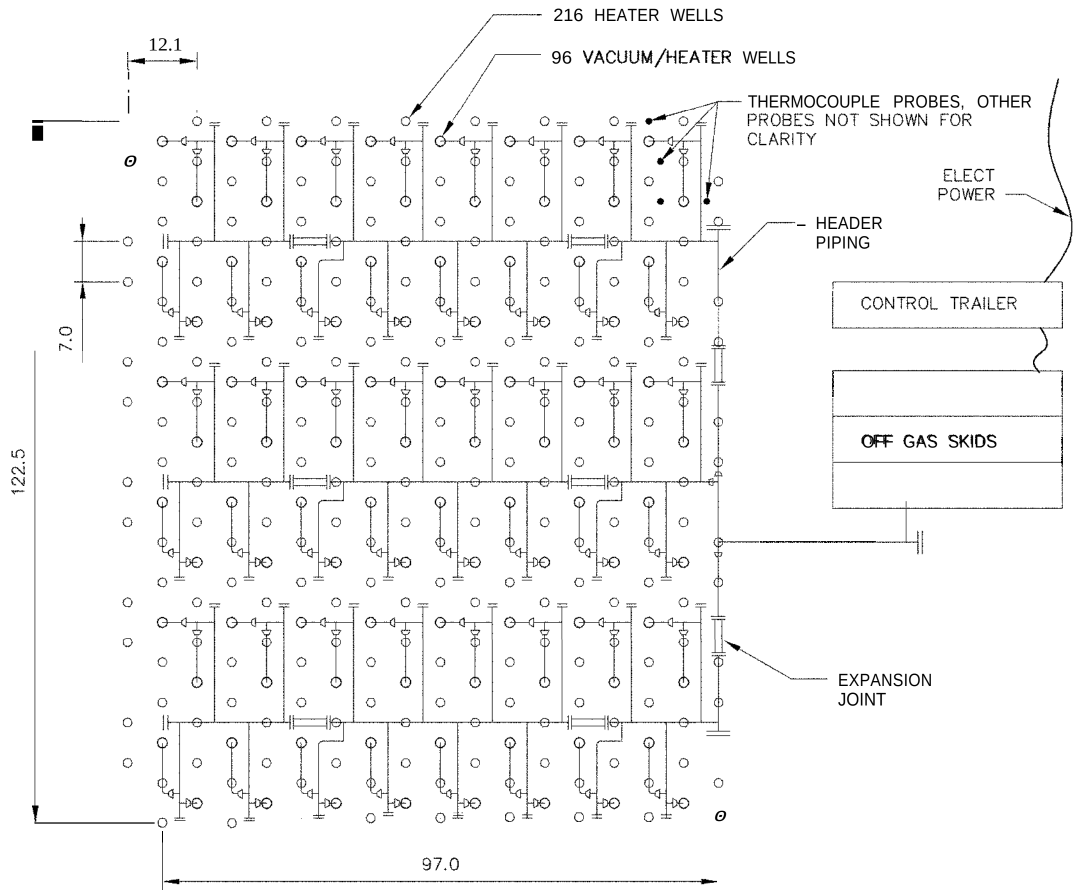

Figure 2-3. Layout of heater wells and vacuudheater wells in a single module over 0.27 acres.

During installation, heater well casings, vacuudheater well casings, soil pressure probes, and thermocouple probes will be driven into the ground using a roto-percussion drill rig (Figure 2-4) until the required depth is reached or refusal is encountered. Refusal is expected to be at basalt. This depth varies from 22 to 31 ft, including the additional overburden. Drilling fluid will not be used and no drill cuttings will be produced.

2.4.1 Heater Wells

Heat will be applied through resistive heater elements placed in a 3-in.-diameter, 1/4-in. wall thickness, stainless steel well casing (as shown in Figure 2-5). The heater elements will be located below the 10-ft layer of overburden soil within the waste zone. The heater will be capable of injecting about 300 watts per linear foot over the 12-ft length. Once the well casing is buried, the heater portion of the well will begin 1 ft from the bottom of the overburden and extend all the way down to basalt. A thermocouple will be placed inside the heater well casing to ensure that each heater is operating. A weatherproof junction box will be connected to a 480VAC single-phase power supply and placed on top of each heater well. If the heater or thermocouple is not functioning properly, either can be removed and replaced without breaching the contamination barrier (heater well casing). The lower 20 ft of the heater well casing will be solid with 2-ft extensions added to make up the remaining length. After placement, 2-ft extensions will be removed as necessary to place the top of the well within 2 ft above the ground surface.

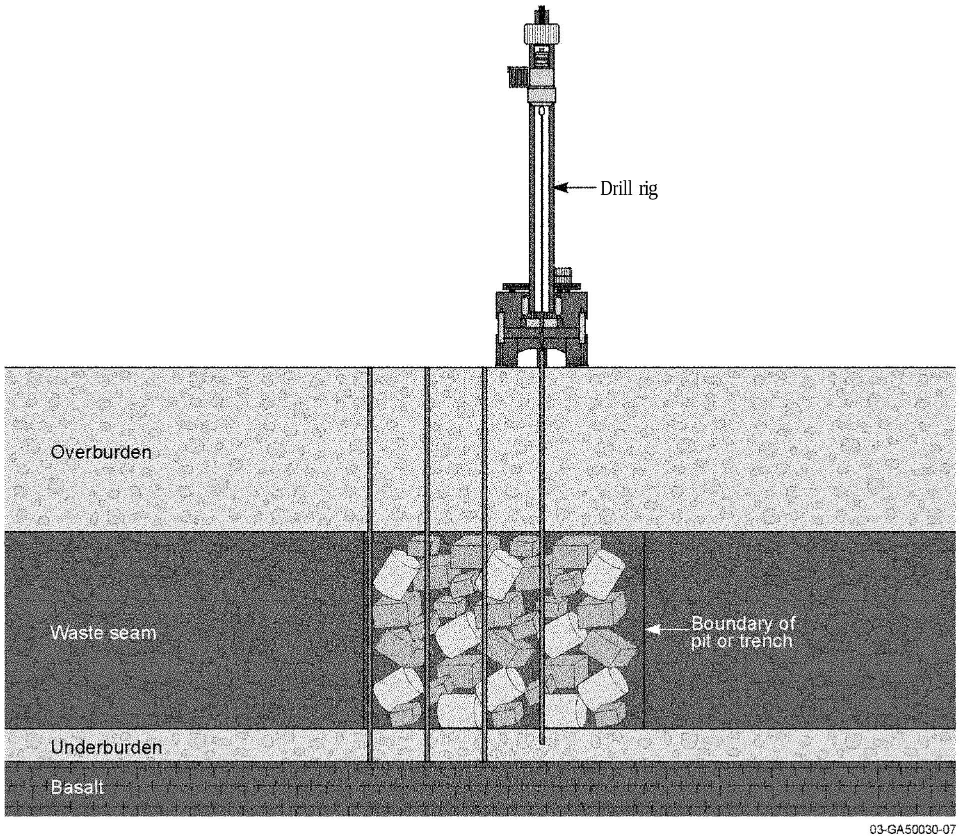

Figure 2-4. Drill rig used in ISTD process.

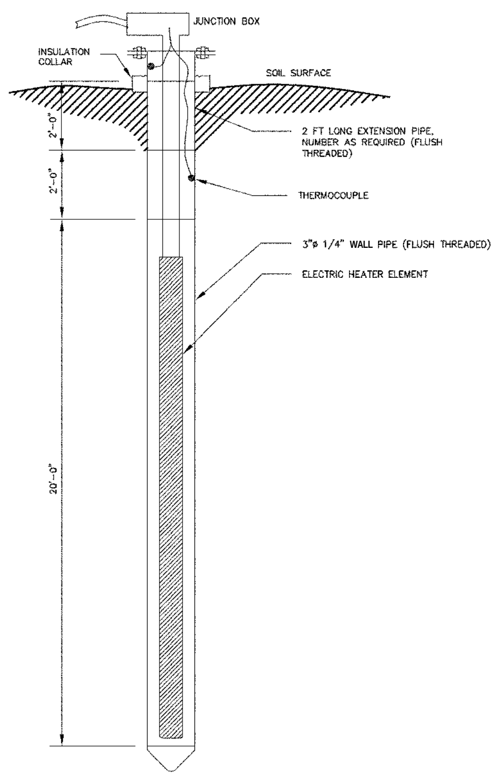

Figure 2-5. Buried heater well.

2.4.2 Vacuum/Heater Wells

The resistive heater elements of the vacuumheater wells are the same as described for the heater wells subsection above. The heater will be capable of injecting about 300 watts per linear foot over the 12-ft length of the well. **A** "heater can" will be located inside of the Vacuum/Heater well casing with sand placed in the annulus between the well casing and the heater can. The sand will serve as a contamination barrier as it will prevent particulate from entering the vacuum well and serve as a roughing filter for the off-gas. If the heater or thermocouple is not functioning properly, either can be removed and replaced without breaching the contamination barrier.

The vacuumheater well casing will be a 4-in.-diameter, Schedule 40 stainless steel pipe (well casing), as shown in Figure 2-7. The casings will have 1/8 in. wide by 6 in. long straight-sided slot perforations located at 1 ft 0 in. on center longitudinally in staggered rows (see Figure 2-6). The slots will be cut at a 45" spacing around the circumference. Slots will start within 2 ft of the vacuudheater well bottom and extend upwards 12 ft. The slots will be rotary saw cut or laser cut.

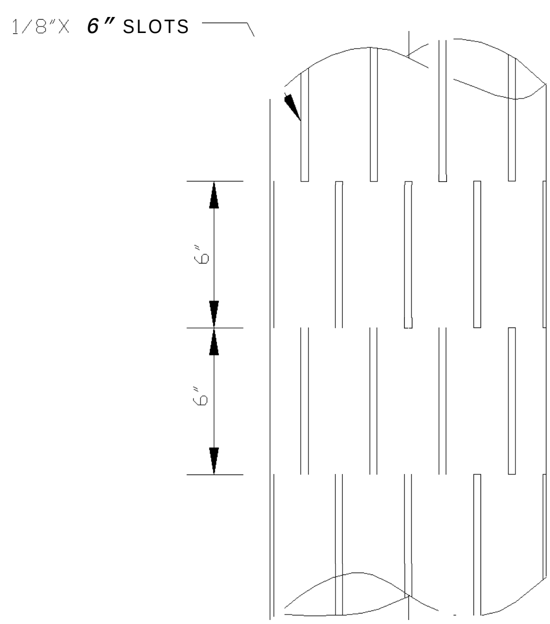

Figure 2-6. Detail of the vacuum slots.

To provide a contamination barrier during heater can and sand installation, the slots will be filled with a high-performance sealant with a melting point of 190°F, which will melt out of the slots prior to steam generation. The sealant will also prevent plugging of the slots during casing placement using the drill rig.

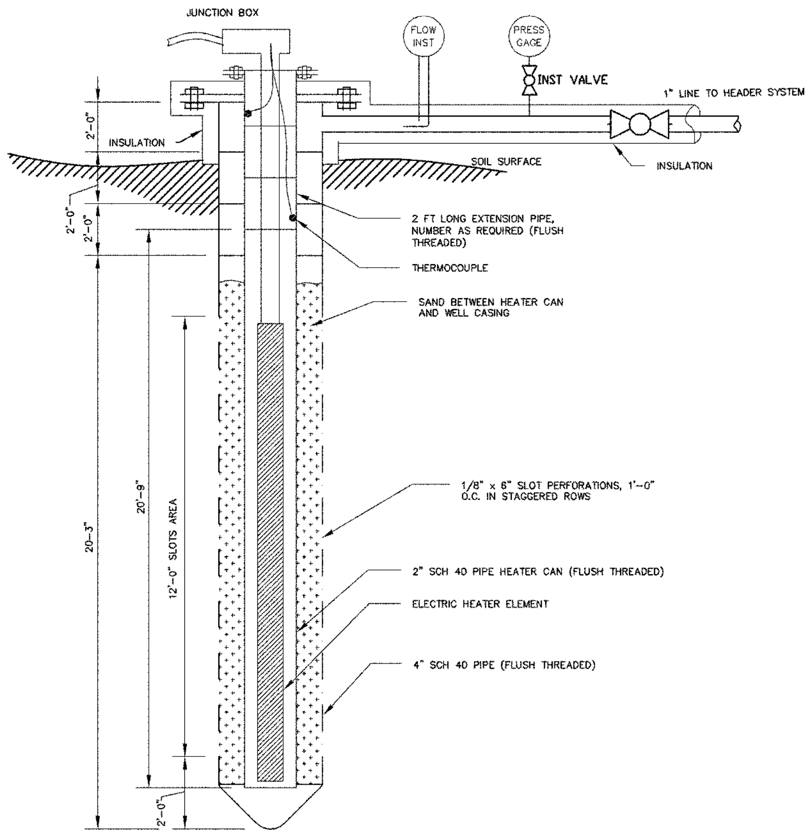

Figure 2-7. Buried vacuudheater well.

The top of the vacuumheater well casing will have a piping connection installed at the correct elevation within the 2-ft extension to mate up to the piping network. **A** survey will be performed to determine the correct elevation for this connection for each individual well casing. The individual extension pieces will then be taken to the fabrication shop and cut to the correct height.

2.4.3 Header Piping Network

The header piping network will connect to each vacuudheater well to collect the soil off-gas and transport these gasses to the off-gas treatment system. The blower on the off-gas treatment skid will provide a vacuum of approximately 40 in. water column (WC). Prior testing has shown that a vacuum of approximately 20 in. WC applied to the vacuudheater well casing with sand filler will provide collection of the anticipated off-gas production. This off-gas production is estimated to be a maximum of 15 scfm per well. The off-gas treatment system will be sized for a maximum of 1,500 scfm total flow rate.

The piping header network will be sized for 15 scfm per well with an overall pressure head loss of 20 in. WC between the off-gas skid inlet and each vacuumheater well casing. It is anticipated that the header piping will be 4-in. diameter within the area of the wells and 6-in. diameter at the blower inlet. Branch piping from the header to each well will be 1–2-in. diameter.

The off-gas will be approximately 800°F at the wellhead at the end of the heating cycle after passing the heaters (which are operating at 1,472°F); therefore, the piping will be subjected to a thermal expansion of approximately 7 in. per 100-ft length, due to the extreme temperature variation of -20°F to 800°F. Expansion loops or joints will be required on each run of header piping.

Piping will be supported at each wellhead and at tops of heater wells. The piping is routed over the heater wells for support, as shown on Figures 2-5 and 2-7. These well casings will provide adequate support since they are closely spaced and are driven to bedrock during installation. This method of support ensures the piping system will not be affected by soil subsidence.

Header piping material is anticipated to be 300 series stainless steel (SST) with low carbon content. Low carbon content lowers the intergranular corrosion due to carbide precipitation during welding operations. Normally, acid handling piping systems are constructed of plastic-lined carbon steel; however, the vacuundheater well off-gas temperature of 800°F exceeds the allowable operating temperature of any of the plastics or fiberglass reinforced plastics. Nickel alloy piping materials such as 20-Mo-6®, Hastelloy®, and Inconel® are compatible with both oxidizing (acids) and reducing (halide ion) environments at both low and high temperatures. These alloys, however, cost ***3*** to 7 times more than SST materials. If the piping network is maintained above the condensation temperature of the acids, SST materials will resist corrosion.

Insulation will be installed around the top of the heaterhacuum wellheads and piping network to prevent condensation of chlorinated hydrocarbons, which produce dilute hydrochloric acid when combined with water vapors. Heat trace will be installed to maintain the wellheads and piping network temperature. Thermocouples will be installed under the insulation to ensure the piping temperature does not go below the condensation temperature of approximately 270°F for sulfuric acid. Condensed hydrochloric acid is corrosive to stainless steel and causes stress corrosion cracking.

It is anticipated that the heater elements in the heaterhacuum wells will be able to maintain the off-gas above the condensation temperature; however, if future testing shows this is not the case, insertion cartridge heaters will be required in the end of each branch while the network is heating up. The branch piping from the vacuundheater wells to the header will then be constructed of nickel alloys to prevent corrosion during the heat-up phase of operations. A standby diesel generator will provide standby power for the off-gas treatment system and heat tracing in case of a power interruption.

A valve will be installed on each vacuundheater well off-gas line as shown in Figure 2-7. These valves are required to maintain the vacuum and allow balancing the flow rates from each vacuundheater well. This valve may also be required to isolate a vacuum/heater well from the piping network for maintenance.

Instrumentation will be required at each wellhead to measure the off-gas flow rate and pressure. The flow rate will be measured by installing a pitot tube in the well outlet pipe. The Pitot tube will be connected to a differential pressure gauge, which will give local airflow velocity readout in feet per minute. A vacuum pressure gauge will also be installed on the outlet pipe to assist in balancing the system. Additional instrumentation will be installed on the headers to maintain overall system flow balance.

2.4.4 Soil Pressure Monitors

To ensure that ISTD is operating properly during treatment and to demonstrate regulatory compliance, soil pressure will be monitored and vapor will be sampled at discrete points in the well field to ensure that negative pressure is maintained in the waste matrix and that soil gases are not leaving the well field. A number of soil pressure probes will be placed around the perimeter and at discrete points within the well field.

2.4.5 Thermocouple Probes

Temperature profiles will be measured in situ to control heat input into a given area and to determine when the ISTD process has achieved the remediation goal. Thermocouple probes, constructed of 3-in. dia, 1/4-in. wall SST tubing (each containing two or more thermocouples) will be driven into the soil/waste matrix to basalt for monitoring the waste temperature. The probes will be installed equidistant between the heater wells and the heater/vacuum wells. Data loggers located in the control room will be used to monitor and record the waste temperatures. The number of thermocouple probes will be determined to meet Data Quality Objectives using statistical methods.

The Data Quality Objectives will be developed in accordance with DOE/ID-10587, Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10, and Inactive Sites, Guidance for the Data Quality Objective Process, EPA QA/G-4, EPA/600/R-96/055, and Data Quality Objectives Process for Superhnd, Interim Final Guidance, EPA/540-R-93-07 1, 1993.

2.4.6 Water Collection Ground Cover

Vaporizing moisture entrained in the soil/waste matrix requires the greatest portion of the energy input. In order to prevent additional water from seeping into the ground, a water collection groundcover will be required. Prior to application of the ground cover, the soil surface will be graded and contoured to drain most of the rainfall away from the treatment area.

The ground cover will be a two-component system consisting of an underlying geotextile, followed by a spray-applied, impermeable urethane coating. Since breaching of the cover will likely occur in subsidence areas, the cover will be capable of being cut and repaired. The Heater well casings and the Vacuum/Heater well casings are anticipated to become hotter than the geotextile and urethane coating's melting point during the ISTD process. Prior to placement of the geotextile, insulated collars will be placed over the well casings, as shown in Figures 2-5 and 2-7. These collars will insulate the geotextile and urethane coating from the well casings. Once the collars are in place, the geotextile membrane will be placed. After the piping and electrical conduit is installed, the urethane coating will be sprayed on over the geotextile. During curing, sand will be spread on the urethane coating to create a safe walking surface.

2.4.7 Off-gas Treatment System

The off-gas treatment system will require approximately 1,000 ft^2 of floor space. The equipment will be mounted on four semi trailers as shown in Figure 2-8. Trailer-mounted components include a cyclone separator, high-efficiency particulate air (HEPA) filters, a regenerative oxidizer (which contains a propane burner and two ceramic oxidizing beds), a compact cross-flow heat exchanger, three dry gas scrubbers, three carbon adsorbers, two induced draft fans and an exhaust stack.

One trailer will have the cyclone separator and HEPA filters, a second trailer will contain the oxidizer, and a third trailer will house the dry scrubber, carbon beds, induced draft fan, and stack. The propane system, housed on a fourth trailer, will include the propane tank and piping/valves going to the thermal oxidizer propane burner.

The induced draft fans maintain a negative pressure in the well header piping network and pull the gas stream through the treatment processes on the trailers.

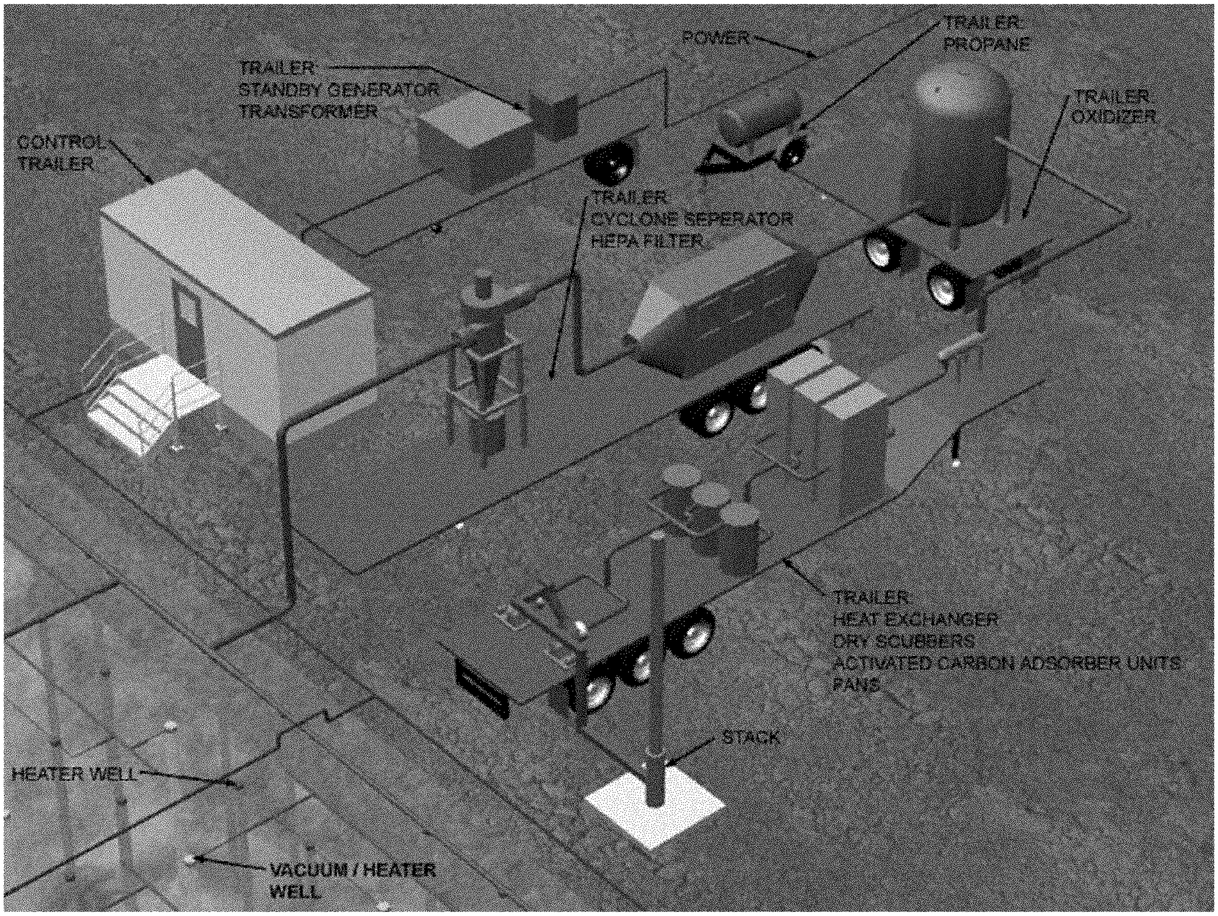

Figure 2-8. Off-gas system and control trailer

Once the soil has been heated, it is essential that a vacuum be maintained throughout the rest of the remediation. In the event of a power outage, a standby generator will be used to maintain power to the off-gas system to ensure that gases are processed through the oxidizer and carbon beds. The heater and vacuudheater wells will be shut down upon loss of utility power to prevent the generation of additional gases.

The overall process system is controlled by a supervisory programmable logic controller (PLC) located within the control room of the trailer. **A** visual monitor displays operating status of system components to the operator through a personal computer.

In addition to system control, the operator's computer will provide data logging. Throughout the off-gas treatment process, vapor stream temperatures and flow rates are monitored and recorded.

Vacuum pressure is measured continuously using Magnahelic gauges, and the temperatures within the oxidizer are monitored continuously using thermocouples. In the event of thermocouple malfunction, the system identifies the defective component, which is then replaced or repaired. Heat exchanger temperatures are monitored at the hot and cold sides of the stream and tied to the process control system. The temperature and circulation rate of the water in the exchanger are adjusted to control the temperature of the vapor stream feeding the dry scrubbers and carbon beds to ensure efficiency and safety.

2.4.8 Support Facilities

The support facilities consist of the control trailer, the propane tank trailer, and the standby diesel generator.

The control trailer will have a control room containing instrumentation and controls for the off-gas treatment system parameters. Remote instrumentation readouts for thermocouples and pipeline flow rates will also be located in the control room. This trailer will have an electrical room which houses the electrical distribution panels and motor control center for the off-gas treatment system, heater wells, heat trace, and lighting. Water lines will not be routed through the control room or electrical room.

The standby diesel generator will be sized to handle such systems as the piping heat trace load, off-gas treatment system, and lighting and critical alarms. The generator will be located adjacent to the off-gas treatment system.

The data collection system will consist of a PLC in the control trailer with remote I/O located near the well field and the off-gas system. The remote I/O will be connected to the main processor through a communications network. The PLC will collect, correlate, and display the field data as required. The operator will have a dual monitor interface that will display the well field temperature profile, system pressures, soil pressure, system flows, and any alarms configured in the system. The operator will also view a graphical display of the off-gas system showing off-gas system parameters. The PLC system will be able to provide Proportional Integral Derivative control of any system parameters, if required.

2.5 Process Description

Two major processes make up ISTD: (1) the thermal desorption and the destruction that occurs underground, and (2) the treatment of the off-gases that are produced during thermal desorption.

2.5.1 Thermal Desorption

In situ thermal desorption is a soil remediation process in which heat and vacuum are applied to subsurface contaminated soil. Heat flows into the contaminated soil by conduction from heaters operated at 750–800°C. As the soil is heated, contaminants are vaporized or destroyed by several mechanisms:

- Evaporation into the air stream
- Steam distillation into the vapor stream
- Boiling
- Oxidation
- Pyrolysis.

The vaporized constituents and degradation products will be drawn by vacuum into the off-gas treatment system. The off-gas system consists of cyclone separators and high temperature HEPA filters to remove particulate, thermal oxidation units to remove trace organics, dry scrubbers to remove acid gasses, and activated carbon adsorbers to remove any remaining contaminants.

Before treatment begins, the area to be treated will be covered by additional soil on top of the existing overburden so that a minimum of 10 ft overburden will be in place to mitigate an underground explosion.

Once the overburden is in place, heater wells and combined vacuudheater wells will be driven vertically through the waste matrix in a hexagonal formation (see Figure 2-9). The wells at the vertices of the hexagon are heater wells containing electrical heating elements. The well in the center of the hexagon is a vacuudheater well, which is used to remove vaporized constituents. Coverage of a particular area to be treated is accomplished by forming an array of adjacent hexagonal units.

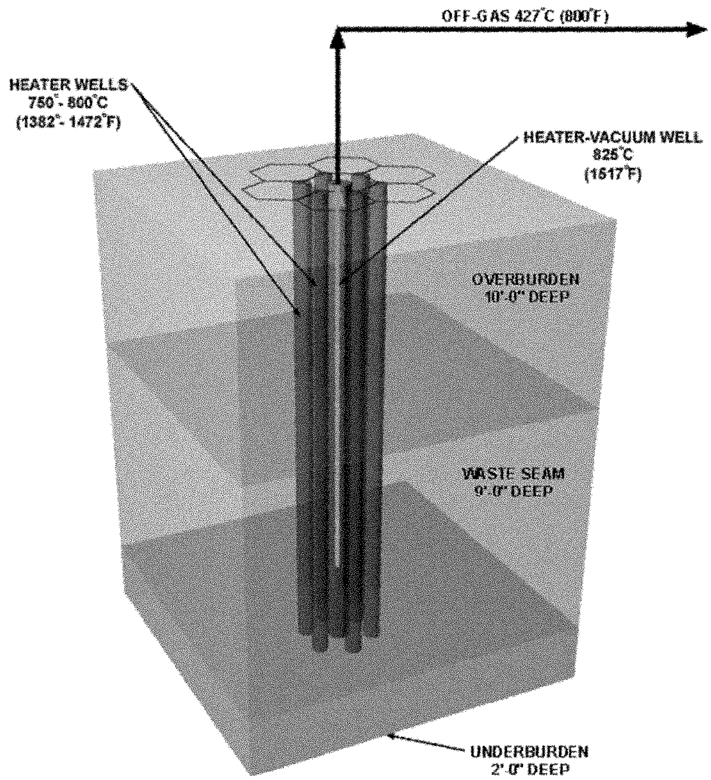

Figure 2-9. The thermal desorption process heats the waste seam and draws the resulting gasses through a vacuum well.

The heater wells conduct heat to the soil and buried waste adjacent to the well casings. As the waste matrix temperature increases, water contained in the interstices between soil particles and the buried waste evaporates and is carried away by the vacuum. The hottest soil contacted by the gas is immediately adjacent to the vacuudheater well, which ensures that the gas temperature rises to the highest possible value. As long as bulk water is available, the soil temperature remains at the boiling point of water that prevails at the local pressure. Many organic compounds are steam-stripped during this boiling phase. Upon exhaustion of bulk water, the soil temperature will increase. Many soil components have associated water, which will also be released as temperature increases. Dehydration of clays causes shrinkage, which increases soil permeability, thus enhancing gas flow through the soil. Increasing soil temperature increases the vapor pressure of organic compounds, which in turn brings organic compounds into the vapor phase. With the oxidizing medium afforded by infiltrating air, hydrocarbons will oxidize to carbon dioxide and water vapor. Chemical equilibrium calculations indicate that halogenated hydrocarbons oxidize to produce carbon dioxide, chlorine, and hydrogen halides such as hydrogen chloride. The off-gases collected by the vacuumheater well are passed to the off-gas treatment system.

Conditions in the waste matrix during ISTD treatment do not favor formation of dioxins and furans;[3] however, dioxins and furans that do form will be destroyed in situ. Additional defense will be provided by off-gas system components designed to destroy chlorinated hydrocarbons that may escape the in situ treatment process. Dioxins and furans that enter the off-gas system will be destroyed in the thermal oxidizer. Additionally, carbon bed adsorbers will adsorb any dioxins and furans not destroyed by the thermal oxidizer. Field experience demonstrates that ISTD is more robust and efficient at dioxin and furan destruction than either ex situ thermal desorption or incineration.

2.5.1.1 Composition of Waste Matrix. All of the waste types treated by ISTD contain small amounts of the TRU elements plutonium and americium. The chemical form of these radionuclides is finely divided metal, which will oxidize in the presence of hot air. Any particulate that is removed from the ground will be contained in the off-gas system by the HEPA filters.

Table 2-1 describes the chemical composition and behavior of the four types of buried waste that will be treated using ISTD. The resulting products will be removed by the vacuum and treated by the off-gas treatment system.

Table 2-1. Waste types treated by ISTD.

Waste Type	Compounds	What happens during ISTD	Resulting products to off-gas treatment system
Organic (743 Sludge)	Carbon Tetrachloride, Tetrachloroethylene (PCE), Trichloroethylene (TCE), Trichloroethane (TCA), Texaco Regal Oil (TRO), Miscellaneous oils, Freon, Polyethylene	All compounds are destroyed.	Water Vapor, Carbon Dioxide, Hydrogen Chloride, Hydrogen Fluoride, Oxides, Nitrogen, Chlorides
Nitrate (745 Sludge)	Sodium Nitrate, Potassium Nitrate, Sodium Sulfate, Sodium Chloride, Polyethylene	Sodium Nitrate, Potassium Nitrate, and Sodium Sulfate decompose, leaving respective oxides. Sodium Chloride does not decompose at ISTD temperatures.	Nitrogen dioxide, Sulfur trioxide, Oxygen, Water Vapor, Carbon Dioxide
Combustible Solids	Cellulose, polyvinyl chloride (PVC), Polyethylene	All compounds are destroyed.	Water Vapor, Carbon Dioxide, Hydrogen Chloride.
Graphite	Carbon, Polyethylene	All compounds are destroyed.	Water Vapor, Carbon Dioxide

2.5.1.2 *Subsidence.* There is a potential for subsidence before, during, and after the ISTD treatment. The waste inside the containers does not occupy all the volume, so when they lose their integrity, subsidence would be expected. Based on drum retrieval studies, virtually all buried drums had lost integrity after 12 years. [4] The decomposition of wastes will create additional voids in the waste matrix, which will increase the potential for subsidence. It is reasonable to expect subsidence during ISTD treatment, and provisions for such events will be made. Future field testing is required to accurately determine subsidence magnitudes.

2.5.2 Off-gas Treatment Process

Each ISTD extraction field covers an area of 0.27 acres (approximately 10,000 ft^2) and down to a total well depth of approximately 21 ft. This well depth consists of 10 ft of overburden (only the bottom 1 ft heated), 9 ft of waste, and 2 ft of underburden soil (heated). With well spacing set at 7 ft, a total of 96 vacuudheater wells are required with a header flow rate of 1,500 scfm. The particle size distribution of entrained solids in the off-gas is assumed to be primarily in the 0 to 10 micron size range with larger particles up to 100 microns. The particle size distribution will have to be verified by laboratory analysis to ensure the correct model input. The overall solids loading on the system is assumed to be small. The ISTD process destroys the organic compounds found in the organic, combustible, graphite, and nitrate drums below the soil surface. Any compounds that escape destruction during the in situ process are directed to the off-gas treatment train to achieve a total of 99.9999% destruction efficiency. The off-gas treatment system will also destroy any halogenated acids, such as hydrogen chloride, that are produced during ISTD.

Figure 2-10 is a block diagram of the ISTD off-gas treatment process. This off-gas system has been designed to meet all applicable permit requirements. Gases, vapors, and solids exit the collection header from the ISTD collection field up to a temperature of approximately 800°F. Dilution air is added to cool the off-gas prior to conditioning and to ensure that the lower explosive limit of the off-gas is not approached during upset conditions. The maximum temperature entering the off-gas system is anticipated to be 438°F.

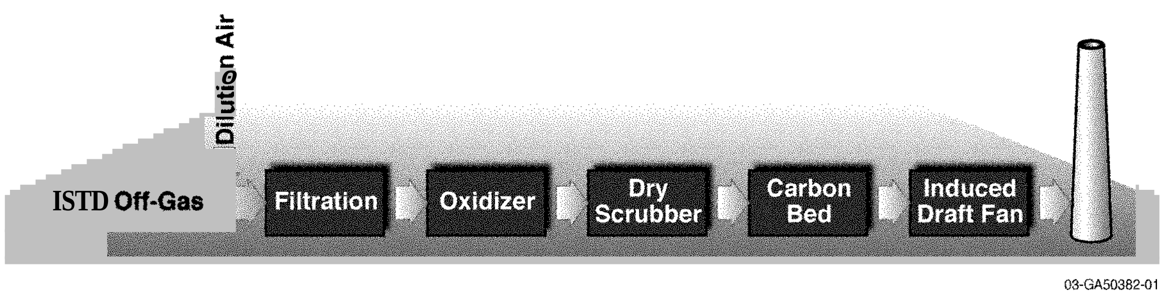

Figure 2-10. The ISTD off-gas system process.

2.5.2.1 *Filtration.* The first stage of filtration, after the dilution, is through a cyclone separator followed by a pair of high-temperature HEPA filter banks configured in parallel. These high-temperature HEPA filters are capable of withstanding exhaust gases up to a temperature of 750°F. One set of HEPA filters is in operation while the other is being replaced. The cyclone separator is designed to remove larger particulates entrained in the off-gas to increase the life of the HEPA filters. Sizing and operation of the cyclone separator depends on the particulate loading in the off-gas. The large particulates are collected from the separator for stabilization using grout prior to disposal. The separator is followed by the HEPA filters to remove 99.97% of 0.3 μm particles. The HEPA filters are designed to remove TRU COCs (Am-241 and Pu-238, -239, and -240) and other radioactive components that may be entrained in vacuum off-gas for hrther conditioning of the off-gas. Each HEPA filter bank consists of five 24 x 24 x 11-1/2-in. filter chambers located in a 300 series stainless steel housing. When the pressure drop across any HEPA filter bank exceeds 5 in. of water, the set of HEPA filters will be replaced. After remediation of the treatment area, the filters will be macroencapsulated in grout (or low density polyethylene) and disposed of.

2.5.2.2 Thermal Oxidizer. Following the HEPA filter, the diluted off-gas enters a flameless regenerative thermal oxidizer. The thermal oxidizer is used to destroy any halogenated organic compounds that may have been thermally desorbed from the waste stream and did not become oxidized in the subsurface. The thermal oxidizer operates by firing a propane burner to heat ceramic media in two heat exchanger beds to a temperature of 1,700°F. The burner is then extinguished and the off-gas is directed through bed 1 of the heat exchangers and then through the other bed (bed 2) to the exhaust. After 4 minutes, poppet flow control valves direct the input off-gas through bed 2 and then on into bed 1, and then through the oxidizer exhaust. If the input gas stream to the oxidizer has chlorinated hydrocarbon content, the exit temperature of the flameless oxidizer is expected to be 1,057°F. If the input gas stream does not contain hydrocarbons, this temperature is expected to average approximately 500°F. The temperature of 1,057°F is not hot enough to produce thermal NO_x, but it is hot enough to ensure oxidation of the COCs to carbon dioxide, water vapor, oxides of nitrogen, and hydrochloric acid. The model of the thermal oxidizer that will be used gives a predicted output of NO, of 110 ppm. This relates to an output of 1.54 lb/hr or 6.6 tons per year in the exhaust stack. This level is below the regulatory level of 40 tons per year for units at the RWMC.

2.5.2.3 Heat Exchanger and Dry Scrubbing Unit. Following the flameless thermal oxidizer, the off-gas is cooled in a compact (cross flow) heat exchanger. Water at 100 gpm is the cooling medium to cool the off-gas from 1,057°F to 250°F before passing into the scrubbing unit. A temperature transmitter on the heat exchanger gas outlet is used to modulate a flow control valve on the water inlet to ensure the correct exit gas temperature to two of three granular dry scrubbing units. The scrubbing units are operated such that two of the scrubbing units are in operation as primary and polishing units, while the other is either undergoing replacement or is in standby mode. The purpose of the scrubbing unit is to remove the acid gases that are present in the off-gas. The unit will also remove organics compounds such as dioxins/furans and any unanticipated quantities of mercury.

2.5.2.4 Carbon Bed Adsorbers. Following the dry scrubber, the off-gas is passed through two of three carbon bed adsorbers to collect any remaining hydrocarbons. The three beds will be arranged so that two beds are in operation as primary and polishing units while the other bed is regenerating. A disposal path for the hydrocarbons that are removed from the carbon beds during regeneration will have to be determined. The spent carbon and hydrocarbons will be disposed of at the INEEL CERCLA Disposal Facility. If mercury (elemental) is present in the off-gas stream, sulfur-impregnated carbon can be utilized in the beds to collect the mercury. The carbon can then be amalgamated and disposed of at the completion of the remediation. A regular, scheduled program to sample the influent and effluent of the dry scrubbers and carbon beds will be initiated to ensure that a breakthrough of organics and acid gasses does not occur on any of these vessels.

2.5.2.5 Induced Draft Fans. Two 100% induced draft fans are available to maintain a vacuum on the off-gas system and to provide a negative pressure on the vacuundheater wells. One fan is in use while the other is used as a spare in case of a malfunction. A variable speed drive is used on each of the fans. The vacuum at the inlet header manifold is measured and used to control the speed of the fans, which in turn controls the vacuum produced. This design is used to control any pressure spikes in the off-gas collection system. It is anticipated that approximately 20 in. of vacuum will be present at the extraction well outlet header. The off-gas treatment train is expected to produce a pressure drop of 20 in. of water. This leads to a total of 40 in. of water vacuum that has to be pulled by each of the fans. The discharge of the fans is directed to an exhaust stack equipped with continuous emission monitoring equipment to confirm regulatory compliance for off-gas emissions. This Continuous Emission Monitoring utilizes an extractive sample probe and conditioning system. The sample stream will be analyzed with a nondestructive infrared analyzer for CO and CO_2. O_2 is measured using a zirconium oxide detector, and Total Hydrocarbons are measured using a flame ionization detector. The radionuclides content of the off-gas will also be measured. Continuous Emission Monitoring data will be collected electronically and displayed graphically. The data will be stored using computer software and may be retrieved at any time. Stack emissions will be sampled during operations (following EPA methods and procedures) and analyzed to specific quality assurance and quality control criteria. The first sample is collected upstream of the dry gas scrubbers, and the other samples are collected upstream and downstream of the carbon beds (this second sample, taken downstream of the carbon beds, is representative of the actual stack emissions).

A standby diesel generator will be provided to the entire off-gas system to ensure that no release of toxic material occurs because of loss of power.

2.6 Confinement Systems

The project confinement systems consist of the soil overburden, the sand fill within each well, soil pressure monitors, the off-gas collection system, and the off-gas treatment equipment and associated piping.

2.6.1 Soil Overburden

The existing waste seam is overlain by approximately ***3*** ft of soil overburden material. Prior to treatment, this overburden layer will be covered by additional compacted soil to a total depth of at least 10 ft. This additional layer serves the dual function of 1) mitigating safety concerns because of a potential underground explosion, and 2) providing primary confinement of the radionuclides and hazardous constituents that currently exist or that may be generated during treatment.

Due to high void space volume and the nature of the treatment method, subsidence events in the treated waste seam are anticipated. Since it is not expected that these events will be sudden nor catastrophic, subsidence areas will be filled with additional soil overburden material as they occur. An operational crew will visually monitor for subsidence and fill any voids as they occur. Based on the information available, the deepest anticipated subsidence (after a series of subsidence events has occurred) is approximately 9 ft.

The initial soil overburden and any additional fill will be compacted. Since the soil overburden portion will not be heated during treatment, void volume in this overburden layer is expected to remain constant and provide reliable confinement.

2.6.2 Sand Fill

Sand is used as fill around the annulus created by the inner and outer well casings for the heaterhacuum wells. This sand, among other functions, serves to significantly reduce migration of radioactively contaminated particulates and most hazardous constituents into the off-gas collection system.

2.6.3 Vapor Monitors

Vapor probes placed around the perimeter of the treatment area will monitor whether any soil gasses are escaping.

2.6.4 Off-gas Collection System

The piping network used to collect the hot gases for delivery to the treatment system will be stainless steel piping system with seal-welded joints. Prior to operation, the entire piping system will be required to pass design pressure tests.

2.6.5 Off-gas Treatment System

The off-gas treatment system is also a fully closed system. Each component upstream of the fan is sealed against inadvertent release of off-gas containing hazardous or radioactive constituents. Prior to operation, the entire off-gas system will be tested and shown to be adequately sealed under design pressures.

2.6.5.1 Normal Operating Conditions. Under the applied vacuum, air is drawn through the soil from the perimeter of the treatment area and the treatment area itself. This air mixes with the hot process gases that pass through the slots in the heaterhacuum wells and up into the collection system under a constant vacuum created by the induced draft fan. The off-gas is monitored continuously at various stages of the off-gas treatment to ensure effectiveness of the treatment process and to ensure compliance with state and federal effluent requirements.

2.6.5.2 Upset Conditions. Upon a loss of normal power a diesel generator will continue to provide power to the off-gas system and associated instrumentation only.

All off-gas controls operate in normal mode during upset conditions. Automatic interaction with these controls may be required by the detailed fire hazards analysis. If required, a discussion of these controls will be included in the PDSA.

2.6.5.3 Passive Safe Shutdown. The system is designed and constructed so that active systems are not required to achieve and maintain confinement in a safe shutdown condition. A passive shutdown strategy is an integral part of the overall system design.

The passive shutdown design ensures that in the scenario of a complete failure of all systems including a loss of power, the off-gas collection and treatment system will maintain a configuration in which no unfiltered paths to the environment exist.

2.7 Safety Support Systems

Safety support systems are radiological monitoring instrumentation, nonradioactive hazardous material monitoring, effluent monitoring, closed circuit television, and fire protection. Each of these systems is described in the following subsections.

2.7.1 Radiological Monitoring Instrumentation

Radiological monitoring instrumentation will include alpha and beta-gamma continuous air monitors (CAMs) or equivalent for airborne radioactivity monitoring in areas of normal work activities. A low background alpha-beta bench top scaler, Protean MPC-2000B-DP or equivalent, will be located in the Support Trailer for contamination survey counting. Radiation area monitors (RAMs) are located in close proximity to the Support Trailers to alert personnel to high radiation fields. Stationary personnel contamination monitors, such as an Eberline PCM-2 or equivalent, will be located at normal egress points. Whole-body surveys will be required. Portable radiological survey instrumentation will be available, including radiation and contamination monitoring instruments, which will be maintained under control of the Radiological Control organization. Air monitoring of the off-gas system exhaust will be conducted to evaluate any airborne radioactivity released to the environment. The Radiological Control Information Management System will be used, as required, for access control to the work areas. This system includes the use of electronic dosimeter to track radiation exposures.

2.7.2 Nonradioactive Hazardous Material Instrumentation

Portable instrumentation may include personal exposure monitors, personnel-exposure sample pumps and media, and environmental contamination monitors. Nonradioactive hazardous material instrumentation will be maintained under control of the industrial hygienist assigned to the project.

2.7.3 Effluent Monitoring System

The exhaust stream from the off-gas trailer exhaust flow will be monitored continuously for the release of hydrocarbons and radionuclides. The monitoring system will consist of an isokinetic system and a Constant Air Monitor.

The isokinetic system will meet ANSI and Health Physics Society standard ANSI N13.1-1999. One sample actively monitors for alpha and beta/gamma radiation, and a second sample provides a sample of record to be sent for analysis. This sample will be evaluated for other hazardous chemicals. The representative samples will be obtained by using shrouded probes. The samples are sent back to the exhaust after analysis. See Section 2.5.2.5 for a description of where each sample is taken.

The ALPHA 7 Constant Air Monitor will provide real-time monitoring to deal with the event of a failure of the HEPA filter system

A climate-controlled cabinet will be located at the base of the exhaust where the sampling and monitoring instrumentation will be located. Three annunciators for the cabinet will indicate low flow, low sample flow, and radiation alarms.

2.7.4 Fire Protection

Specialized fire protection systems will be located adjacent to the support trailer. These fire protection systems may contain specialized extinguishing agents (e.g., MET-L-X, NAX, or Multipurpose dry chemicals).

2.7.5 Portable Fire Extinguishers

Portable fire extinguishers rated for A-B-C fires will be located at exit doors of the Control Trailer and other areas of the VTA.

2.8 Utility Distribution Systems

2.8.1 Facility Water System

The ISTD process will require water for the off-gas treatment process. Water will be trucked to treatment area and stored in a tank for use by the treatment process. Potable water for drinking will not be provided in the SDA.

2.8.2 Electrical Power System

Electrical power is supplied from the 12.5kV power line from CFA. The feeder that was to supply the In situ Vitrification Project off the main RWMC 12.5kV supply will be used to supply the power for the ISTD Project.

A 15kV-armored cable will be brought across the surface of the SDA to the treatment area. The armored cable will be relocated as necessary for each change in treatment location. Physical protection for the cable will be fabricated as needed where traffic over the cable is required.

A portable sectionalizer switch and transformer will be placed near the treatment location. The transformer will convert the 12.5kV to the 480V utilization voltage. A standby diesel or propane generator providing 480V to the off-gas system will come on line within 10 seconds of the loss of commercial power to the ISTD system. The critical loads will be fed from a separate power distribution panel. A transfer switch feeding the critical load distribution panel will switch from the commercial power feeder to the emergency generator as soon as the emergency generator comes to full voltage.

The heater well power will be distributed at 480V via a heater control system. Approximately one megawatt will be provided for the heater wells and the vacuudheater wells. This will be sufficient to treat a 0.27-acre area.

The Off-gas treatment process will be fed at 480V and will take approximately 120kW

The 120–208V fed from the 480V distribution system will be utilized for normal “house” loads, lights, and receptacles.

The 24V DC will be utilized for control and instrumentation voltages.

2.8.3 Propane Supply

A 6,000-gal propane supply tank will be located on a trailer near each off-gas treatment system

2.9 Auxiliary Systems and Support Functions

Major roads and other facilities at the RWMC will facilitate ISTD activities.

2.10 Demobilization, Disposition and Decommissioning

After thermal treatment of the 2.6-acre area at the SDA, the peripheral equipment will be removed from the treatment site, decontaminated to the extent possible, if necessary, and dispositioned. Disposition could consist of packaging and disposal in a CERCLA disposal facility or excessing. The piping manifolds will be left intact connected to the wells and pumped full of cement grout. The exposed piping will be covered with a layer of soil to create a smooth working surface. The entire 2.6-acre area will then be jet-grouted using the system and equipment defined in the in situ grouting FS-PDSA.

2.11 References

1. *Waste Area Group 7 Geographic Information Systems WasteOScope Application,* INEEL/EXT-02-00292, Rev. *0*, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho, March 2002.

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3. Baker, R. **S.** and LaChance, J. C., *In-Situ Thermal Desorption ('ISTD) Relative to Dioxins,* TerraTherm, Inc. (www.terratherm.com), November 2002.

4. Arrenholz, D. A. and Knight, J. L., *Historical Report **of** Transuranic (TRU) Waste Pits and Trenches at the Subsurface Disposal Area (SDA) **of** the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory (INEL),* WTD-91-027, August 1991.